REMARKS/ARGUMENTS

The application has been amended so as to place it in condition for allowance at the time of the next Official Action.

The Official Action stated that the title of the invention was not descriptive. Accordingly, the title of the invention has been amended throughout, declaration excepted, to DEVICE AND METHOD FOR MEASURING WEAK CURRENT SIGNALS USING A FLOATING AMPLIFIER.

The Official Action asked for a substitute specification. Responsively, a substitute specification is being provided. The undersigned verifies that no new matter is being entered.

The Official Action rejected claims 1-9 under §112, first paragraph, as containing subject matter not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventors, at the time the application was filed, had possession of the claimed invention.

The Official Action specifically refers to the disclosure of the floating amplifier and the mounting of the double bootstrap type.

Applicant respectfully tranverses this rejection in that when the originally-filed disclosure is completely read and considered by one of skill in the art, the disclosure is understood and indeed conveys that the inventors, at the time of

the application being filed, had possession of the claimed invention.

In general, the present application uses an amplifier called a floating amplifier, when its supply voltage is not fixed. In fact, this supply voltage follows the supply voltage of the shunt as disclosed and recited. Therefore, the present amplifier is indeed a floating amplifier. Applicant believes that the term "floating amplifier" is known within the art and, in any event, the meaning of the term is disclosed within the description of the preferred embodiments.

As to the bootstrap mounting, a bootstrap mounting is a special known mounting, as explained on page 8, lines 17-20 of the specification which supplies voltage to the amplifier. In lines 17-20 of page 8, the disclosure is to a positive bootstrap, as the amplifier is connected to the battery 2. This type of mounting is commonly named a positive bootstrap. In lines 21-24 of page 8, the same mounting is used to be connected to ground. This is thought of as a negative bootstrap mounting, by comparison to the positive bootstrap mounting being connected to the battery.

According to the invention, the amplifier 15 receives voltage supplied through these two bootstrap mountings (one positive and one negative). As there are two bootstrap mountings, the application describes the voltage supply as a

double bootstrap type. Although the term "double bootstrap type" is not known, this being part of the invention, applicant believes that the meaning of the term is made clear through the remaining disclosure.

In view of the above, withdrawal of the §112, first paragraph rejection is respectfully requested.

The Official Action rejected claims 1-9 under §112, second paragraph, as being indefinite.

These claims have been amended so as to remedy the stated bases of rejection. Accordingly, reconsideration and withdrawal of the indefiniteness rejection are respectfully requested.

The Official Action rejected claims 1-3 and 7-8 under §102 as being anticipated by CAMERON 4,360,879. The Official Action rejected claims 1-2 and 7-8 under §102 as being anticipated by COOK et al. 4,096,436.

Although not all of the claims were substantively rejected, there was no indication of allowable subject matter.

Applicant has carefully studied the applied references and believes that they do not anticipate the presently-pending claims.

CAMERON does not show any amplifier which is supplied with a voltage that follows the supply voltage of the shunt. Indeed, in CAMERON, amplifier 103 receives between its non-

inverting and inverting port of signal (and not a voltage supply) which is an image of the current going through the shunt 102. The image of the voltage passing through the load is directly fed to the multiplier 104.

Amplifier 103 is not a floating amplifier as its voltage supply is of a classical type, not shown in the drawing or in the specification. The voltage supply of amplifier 103 does not follow the voltage of the supply of the shunt as recited. Further, in CAMERON, the shunt is referenced relative to ground of the measuring circuit.

Mounting elements 132, 133, 135, 136 and 137 are used to measure voltage in the load and constitute attenuation means, filtering means and peak limiting circuit (see column 2, lines 10-28) with references of +V1 and -V1. These components do not at all provide a floating **supply means** for the amplifier 103. Further, a signal processed by these elements is not supplied to amplifier 103 but to multiplier 104.

In view of this, CAMERON does not disclose the features recited by the presently-pending claims and does not show an amplifier with supply means to supply the amplifier with a voltage that follows the supply voltage of the shunt. Indeed, nothing is shown or described in CAMERON concerning the way amplifier 103 is supplied with voltage. The only things that are

disclosed concern the way this amplifier amplifies a current signal.

COOK et al. also do not show any amplifier supply means which follows the voltage supply of the shunt. The amplifier 22 has the same function of that of amplifier 103 in CAMERON. Nothing describes or suggests that amplifier 22 is supplied with a voltage that follows the supply voltage of the shunt. Indeed, nothing is said concerning the supply for amplifier 22. All that is known concerns the signals which are amplified by this amplifier.

In Figure 2 of COOK et al., amplifier 126 is not supplied with the voltage according to the present invention. One only knows how it treats the signals coming at its inverting and non-inverting ports. One also knows that terminals I and VIII of amplifier 126 are bridged by a capacitor 130 which provides frequency compensation for the amplifier as per column 6, lines 16-19. However, nothing is said concerning the way the amplifier 126 is supplied with voltage.

In view of the references not disclosing the features recited in the presently-pending claims, withdrawal of the anticipation rejections is respectfully requested.

Entry of the above amendments is earnestly solicited. Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

Should there be any matters that need to be resolved in the present application, the Examiner is respectfully requested to contact the undersigned at the telephone number listed below.

The Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 25-0120 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17.

Respectfully submitted,

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MARKED-UP COPY OF ORIGINAL SPECIFICATION

DEVICE AND METHOD FOR MEASURING WEAK CURRENT [AND CORRESPONDING PROCESS] SIGNALS USING A FLOATING AMPLIFIER

BACKGROUND OF THE INVENTION

The invention relates to a device and a process for measuring current using the amplification of low value signals. It relates particularly to the field of automobile power steering.

Although the device usually used for automotive vehicle power steering normally uses a DC motor, it is also envisaged to use an asynchronous triphase motor.

DESCRIPTION OF THE RELATED ART

In power steering of an automotive vehicle, it is indispensable, to manage the control strategy, to know the torque applied by the power steering motor, and hence, in the case of a triphase motor, to know the electrical current passing through the three phases. The corresponding measurement is carried out by a shunt [by using] and the conventional formula U = R x I.

Moreover, when the vehicle driver turns the steering wheel slowly, a high demultiplication ratio between the shaft and the steering cannot be used because it would become very difficult

for the driver to turn the steering wheel [in case of] during a system failure [of the system]. It is thus necessary to use a motor with a high torque (in particular for "heavy" vehicles), even at low speed, and to apply to it a vectorial control which is actually the only one which permits a substantial torque at almost zero speed.

In practice, the electric motor used has a power which can be of the order of 500 watts[, and it]. The motor is supplied by continuous chopped voltage (the three phases are obtained by substantially rectangular chopping of the voltage from a vehicle battery, and smoothed by using the self effect of the motor itself). The frequency used is of the order of 15 to 25 KHz (namely substantially the top of the standard audio band).

To measure the voltage [of] across the terminals of a shunt mounted in series [on] with a phase of the electric motor (the shunt oscillating between the ground and the battery voltage, at the cutout frequency), it is obviously desirable to reduce the heat loss by the Joule effect in the shunt ([lost] loss being proportional to the square of the electrical strength passing through the shunt).

The strength [being] here being of the order of 100 amperes, a shunt of 1 [mÙ] mΩ already has a power loss from heat

of 10 watts. It will thus be understood that, because of this, the tendency is to seek to reduce further the value of the shunt.

The consequence of this choice of a low shunt value is that the voltage finally measured at the terminals of the shunt is, for a shunt of 1 [mÙ] mΩ, of the order of 100 mV.

The problem is thus to carry out on the shunt a current measurement that is sufficiently precise, from a voltage whose order of magnitude is about 100 mV, and which acts on a chopped voltage from the 12 volt battery (the ratio is thus about 1% between the voltage to be measured and the chopped voltage), and chopped at a high frequency of the order of 15 to 25 KHz, in the presence of noise in the chopped voltage, particularly at each voltage shock (rising or falling voltage front).

[The conventional] Conventional differential amplifiers do not permit precise reading of the voltage at the terminals of the shunt, because the measurement is very much disturbed at each chopping transition. Figure 1 shows the signal obtained by [such] a conventional differential amplifier for a value of maximum current.

SUMMARY OF THE INVENTION

The present invention [meets] addresses the problem set forth above, and provides for this purpose[, with the] a

corresponding process[,] together with a device that is simple to make and low cost, permitting amplification and measurement of weak signals.

According to the invention, for measuring current in a line supplied by a voltage with noise and comprising a series-mounted shunt [mounted in series], there is used [an] a shunt signal amplifier [of the signal of the shunt], hereafter called a floating amplifier, and means to supply said floating amplifier with a voltage which follows the supply voltage of the shunt.

It will be understood that the principle of the invention is to amplify the useful signal to facilitate its extraction from the chopped signal. To do this, the [amplifier of the] shunt signal amplifier is supplied with a voltage which follows the shunt potential [of the shunt].

The invention similarly provides for the application of the device and of the process which is its object, to a current measurement in a supply line of an asynchronous motor.

According to particular arrangements that may be used in combination:

[- the] a triphase electric motor [is of the triphase type,

- the electric motor is] supplied by a chopped voltage,

[-] the electric motor [has] having a power of about 500 watts, together with a

[- the] shunt [has a value] of about 1 [mÙ] mΩ,

[-] the device [comprises] comprising a differential amplifier whose inputs are connected on the one hand to the input of the shunt and, on the other hand, to the output of the so-called floating amplifier, where

[-] the floating amplifier has its inputs connected to the terminals of the shunt and is supplied from a double bootstrap type mounting [of the double bootstrap type].

These arrangements are favorable to a production of the device with conventional components, without particular requirements and hence of low cost, which makes the production of the device economical.

Finally, the invention provides, according to another aspect, the application of the device and of the process which is its object, to electrical power steering for an automotive vehicle.

Generally speaking, when there is involved a measurement of weak current in a line supplied by a voltage with noise, and comprising a series-mounted shunt [mounted in series], the process of the invention is characterized in that it comprises the step of

signal amplification of the potential difference between the input and output terminals of the shunt by an amplifier supplied by a voltage which follows the supply voltage of the shunt.

Preferably, it moreover comprises a step of differential amplification of the difference between, on the one hand, the signal of the chopped voltage at the input of the shunt, and, on the other hand, the potential difference at the terminals of the shunt, amplified by the floating amplifier.

It is important to note that this problem of measuring weak current in the shunt in the presence of voltage noise is in fact new in an application of electrical power steering, to the extent to which most of the previously existing devices used DC motors, of lower power (100 to 150 watts). There thus was no particular problem to measure a voltage at the terminals of a shunt connected to the ground or to the battery voltage (because of the absence of chopping).

Present DC motors operate by using brushes, which give rise to a problem of wear, and which would not be usable in practice for motors of 500 watts. Moreover, the choice of having a constant torque no matter what the steering, and to reduce "torque oscillations" that now exist in power steering with DC motors with brushes, leads to using triphase asynchronous motors,

and hence to introduce a chopped voltage, comprising a not inconsiderable voltage noise.

The invention is thus applicable more generally to all so-called "brushless" electrical motors, or to motors which do not operate with DC.

BRIEF DESCRIPTION OF THE DRAWINGS

The description and drawings which follow permit better understanding the objects and advantages of the invention. It is clear that this description is given only by way of example, and not in a limiting way.

In the drawings:

- Figure 1 shows the noise present in a chopped voltage supplying a triphase electric motor,
- Figure 2 shows schematically a device for measuring a signal from a shunt, not according to the invention,
- Figure 3 shows schematically, in an analogous manner, a measuring device according to the invention,
- Figure 4 shows the measured signal, after use of the device according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As is seen in Figure 2, a triphase asynchronous motor 1, for example adapted to act on an automotive vehicle steering, is supplied by a battery 2 (of the 12 volt type) via three supply lines 3, 4, 5. A chopping device 6, of a conventional nature (rapid switch), and not shown in detail here, is inserted in each supply line of the motor 1, as is also a control device (not shown) for the motor 1.

It is thus sought to determine the current flowing in the electrical lines 3, 4, 5. To do this, a low current measuring device 7 is [disposed] located in one supply line (here designated 5) [for supplying the motor 1].

This device 7 first of all comprises a shunt 8, of conventional type, of a value of about 1 [mÙ] mΩ, and an amplification means, which in the embodiment illustrated in Figure 2 and not according to the invention, is comprised by a differential amplifier 9 mounted at the terminals 12, 13 of the shunt 8 ("+" terminal at the output terminal 13 of the shunt, and "-" terminal at the input terminal 12 of the shunt), and supplied between the battery 2 and a ground 10. A processing device for the measurement 11, not shown in detail here, receives the signal from the differential amplifier 9.

It is seen above that the use of such a measuring device gives rise to the observation of a signal as shown in Figure 1, hence with a great deal of noise and difficult to use.

The device according to the invention is thus shown in Figure 3. It will be seen that it comprises, in addition to the differential amplifier 9, whose inputs are connected on the one hand, for the "-" terminal, to the input terminal 12 of the shunt 8, and, on the other hand, for the "+" terminal, at the output 14, to a so-called floating amplifier 15.

This floating amplifier 15 has its inputs connected to the terminals 12, 13 of the shunt 8 ("+" terminal to the output terminal 13 of the shunt, and "-" terminal to the input terminal 12 of the shunt). It is supplied by floating supply means constituted by a mounting of the double bootstrap type.

More precisely, a terminal of voltage VCC of said floating amplifier 15 is connected to the battery 2 through a diode D1. A condenser C1 is mounted between the input terminal 12 of the shunt and the cathode 16 of the diode D1.

Similarly, a voltage terminal GND (or VEE) of the floating amplifier 15 is connected to the ground 10 via a diode D2. A condenser C2 is mounted between the input terminal 12 of the shunt and the anode 17 of the diode D2.

In operation, the chopped signal from the battery has a voltage increasing between 0 and 12 volts. During positive alternation of the chopping (substantially 12 volts), the chopped battery voltage (12+ÄU) (12+ΔU) is imposed on the condenser C2 of "-" supply of the floating amplifier 15, via the diode D2, and the voltage Vee will then be substantially equal to the input voltage of the shunt [(12+ÄU)] (12+ΔU) (terminal 12) LESS 12 volts, namely [ÄU] ΔU. The voltage Vcc is substantially equal to the input voltage of the shunt [(12+ÄU)] (12+ΔU) PLUS 12 volts (discharge from C1), and the difference Vcc-Vee equals 24 volts.

During negative alternation of chopping (substantially 0 volt), this chopped battery voltage [0+ÄU] 0+ΔU is applied to the condenser C1 of "+" supply of the floating amplifier 15, via the diode D1, and the voltage Vcc thus equals substantially the input voltage of the shunt [0+ÄU] 0+ΔU (terminal 12) PLUS 12 volts. The voltage Vee is equal substantially to the input voltage of the shunt [0+ÄU] 0+ΔU (terminal 12) LESS 12 volts (discharge of C2), namely [ÄU] ΔU - 12 volts, and the difference Vcc-Vee equals 24 volts in this case again.

The floating amplifier 15 is thus supplied at a voltage twice that of the battery 2, if influence of switching elements is omitted. And this supply follows the shunt potential

(independence relative to [ÄU] $\underline{\Delta U}$, hence from chopping shocks). There has thus been provided in this case a symmetrical floating supply of the floating amplifier 15, which follows the input potential of the shunt 8.

The floating amplifier 15 thus supplied is accordingly adapted to amplify the signal between the terminals of the shunt 8, independently of the noise existing in the supply voltage.

There is thus amplified by the floating amplifier 15 the difference signal of voltage between the input terminals 12 and the output terminals 13 of the shunt 8.

The differential amplifier 9 operates itself with, as inputs, on the one hand the chopped voltage signal at the input 12 of the shunt 8, and on the other hand the potential difference at the terminals of the shunt 8, amplified by the floating amplifier 15.

The comparison between these signals with a conventional differential amplifier 9 is thus much easier than in the absence of amplification of the potential difference at the terminals 12, 13 of the shunt 8.

Thus, in the absence of amplification of the potential difference at the terminals of the shunt 8, the noise in the supply voltage is high before the difference of voltage at the

terminals of the shunt (value to be measured), and the differential amplifiers hence less satisfactory. On the contrary, after amplification of the potential difference of the terminals of the shunt, the noise in the supply voltage becomes less relative to the amplified signal, and the differential amplifier performs well.

Stated another way, it is possible to carry out measurement of the current with very low shunt values, because with the floating supply used, it is possible to amplify the weak signal obtained, and then to reference this amplified signal to the overall ground, by minimizing the errors introduced in the differential stage.

Figure 4 shows the actual embodiment of the invention, with maximum current, and it will be seen that the distortions of commutation are the exact reflection of the behavior of the power switches.

A significant advantage of this mounting is that it is thus possible to use a differential amplifier 9 of conventional type, and hence of low cost, and similarly to use a floating amplifier 15 which is also conventional and low cost. This contributes to reducing the cost of production of the device.

The scope of the present invention is not limited by the details of the embodiments given above, considered by way of example, but extends on the contrary to modifications within the scope of those skilled in the art.